

AFRL Space Propulsion and Power Workshop
October 17 - 19, 2007
Huntsville, AL

Progress on the PT-1 Prototype Plasmoid Thruster

Richard H. Eskridge, Adam K. Martin

NASA Marshall Space Flight Center (MSFC),
ER24 - Propulsion Research & Technology Applications Branch
Huntsville, AL 35812

The design and construction of a plasmoid thruster prototype is described. This thruster operates by expelling inductively formed plasmoids at high velocities. These plasmoids are field reversed configuration plasmas which are formed by reversing a magnetic flux frozen in an ionized gas inside a theta-pinch coil. The pinch coil is a unique multi-turn, multi-lead design chosen for optimization of inductance and field uniformity. A table-top bread-board demonstrator has been built at MSFC, and will be delivered to Radiance Technologies Inc. for further testing at the Auburn Space Power Institute.

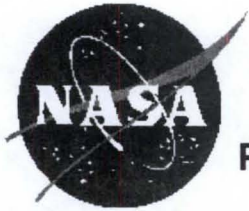


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**R. Eskridge and A. Martin
NASA ER24/ Propulsion Research and Technology Branch
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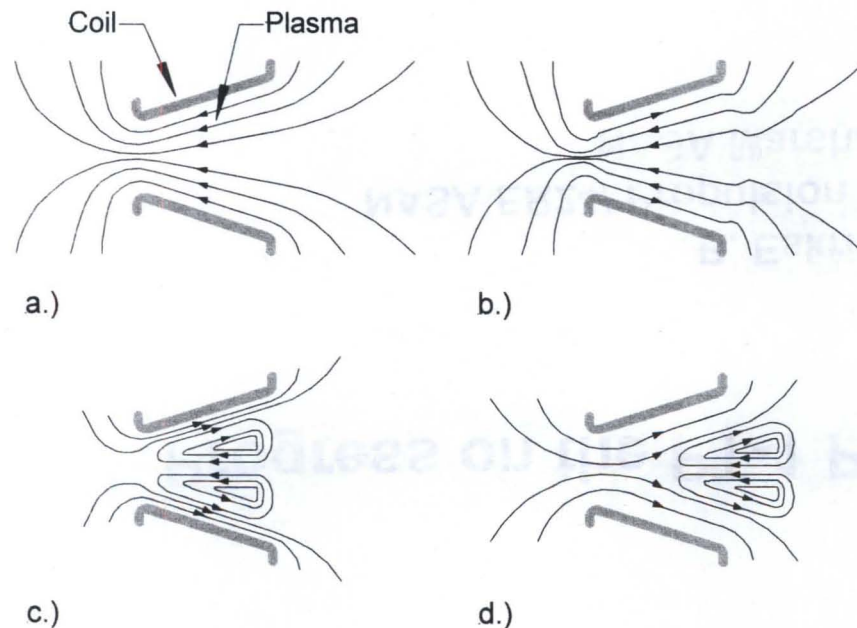


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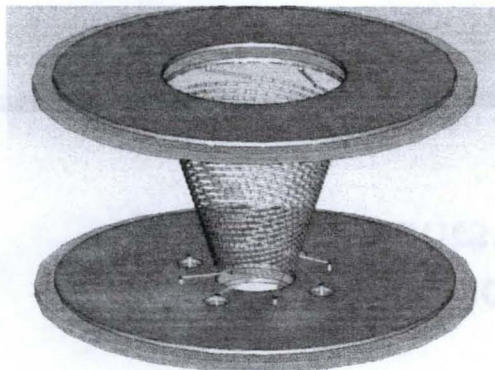
Review- What is a “plasmoid” thruster

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Left: formation sequence of a plasmoid.

- (a) “BIAS” field is embedded in a pre-ionized plasma
- (b) “DRIVE” coil fires and imposes a stronger and reversed field
- (c) The reversed “DRIVE” field intensifies, causing the “BIAS” field lines to break and reconnect, forming a plasmoid
- (d) “DRIVE” field expels the plasmoid from the coil at high velocities



In the PT-1, the “DRIVE” and “BIAS” coils are helically interwound, 4-lead, 3 turn coils, with a 15 degree half-angle conical form.



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Design Considerations for the PT-1 Thruster

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- Based on the PTX results, we sought to build a bread-board thruster for proof-of-concept. The PT-1 design does stray far from the PTX geometry.
- The PT-1 is an expedient prototype for demonstration of the concept at TRL 3-4
- A coil design was chosen to improve the efficiency of the device vs. PTX
- Solid-state switches will be needed for a flight-worthy thruster, however in order to simplify the design for this prototype, spark-gap switches are used. The vacuum spark gap design chosen is usable over a broad range from 50 V to 18 kV.
- Efficiency listed is for full inductive recapture of bank energy.

Design Parameters for PT-1

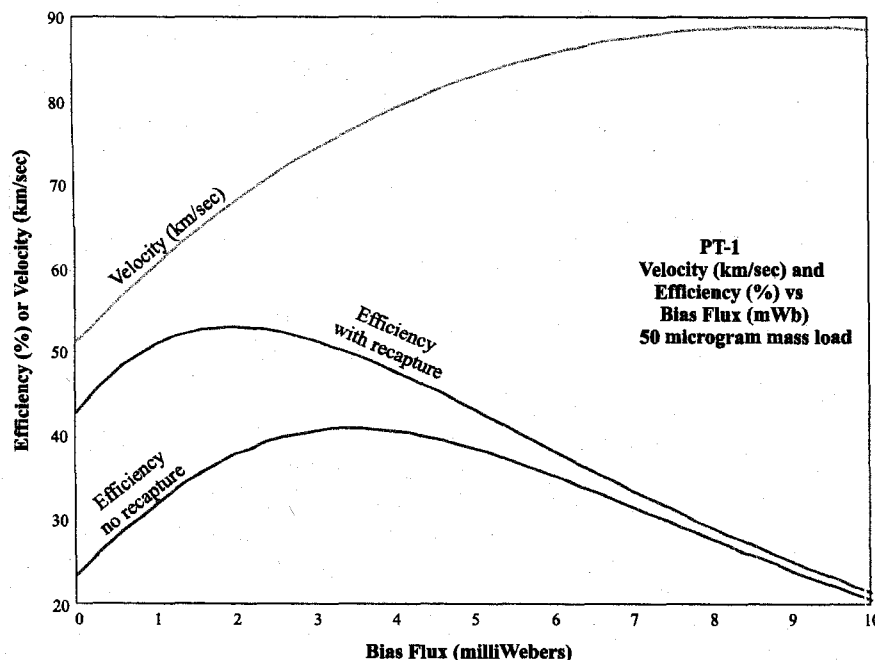
Property	Value
Specific Impulse (s)	5000
Mass / Pulse (μg)	140
Energy / Pulse (J)	280
Repetition Rate (Hz)	30
Jet Power (kW)	5.0
Average Thrust at 30 Hz (N)	0.2
Efficiency (% Nominal)	60
Electrical Input Power (kW)	8.4
Drive Bank Voltage (kVDC)	6.1
Bias Bank Voltage (kVDC)	2.0
Drive Bank Capacitance (μF)	15
Bias Bank Capacitance (μF)	15



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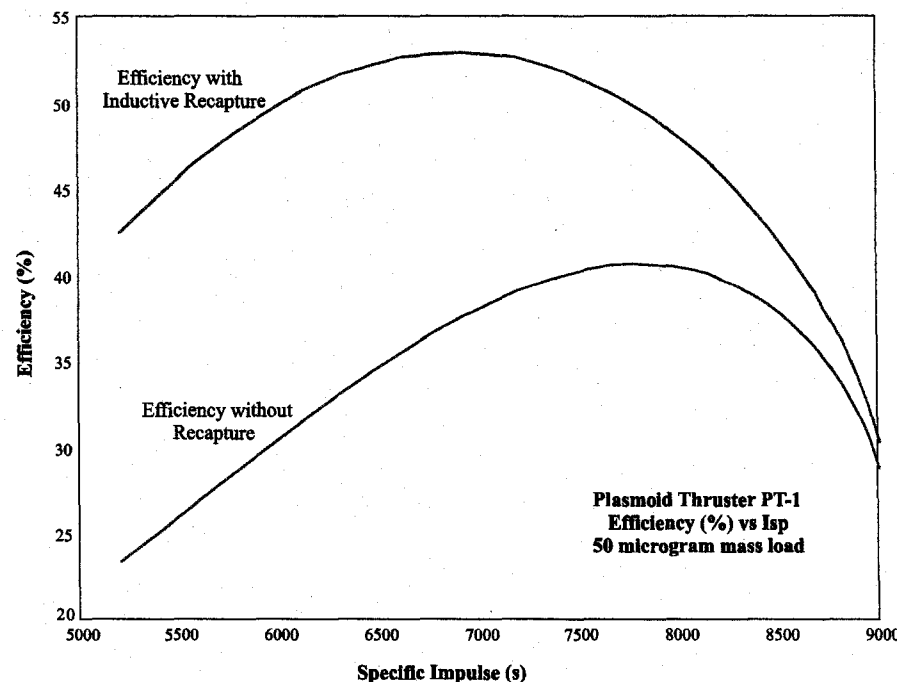
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Left: Velocity and efficiency curve for the PT-1 Thruster using a 50 microgram gas mass load. The thruster can be operated with reasonable Efficiency ($> 50\%$) over a wide range of velocities (and Hence Isp's) by adjusting the mass load and Bias flux.

Right: The Isp and efficiency of the PT-1 For a 50 microgram injected gas mass load. The Plasmoid Thruster scales favorably- model results indicate that thrusters larger than PT-1 may be as much as 90% efficient



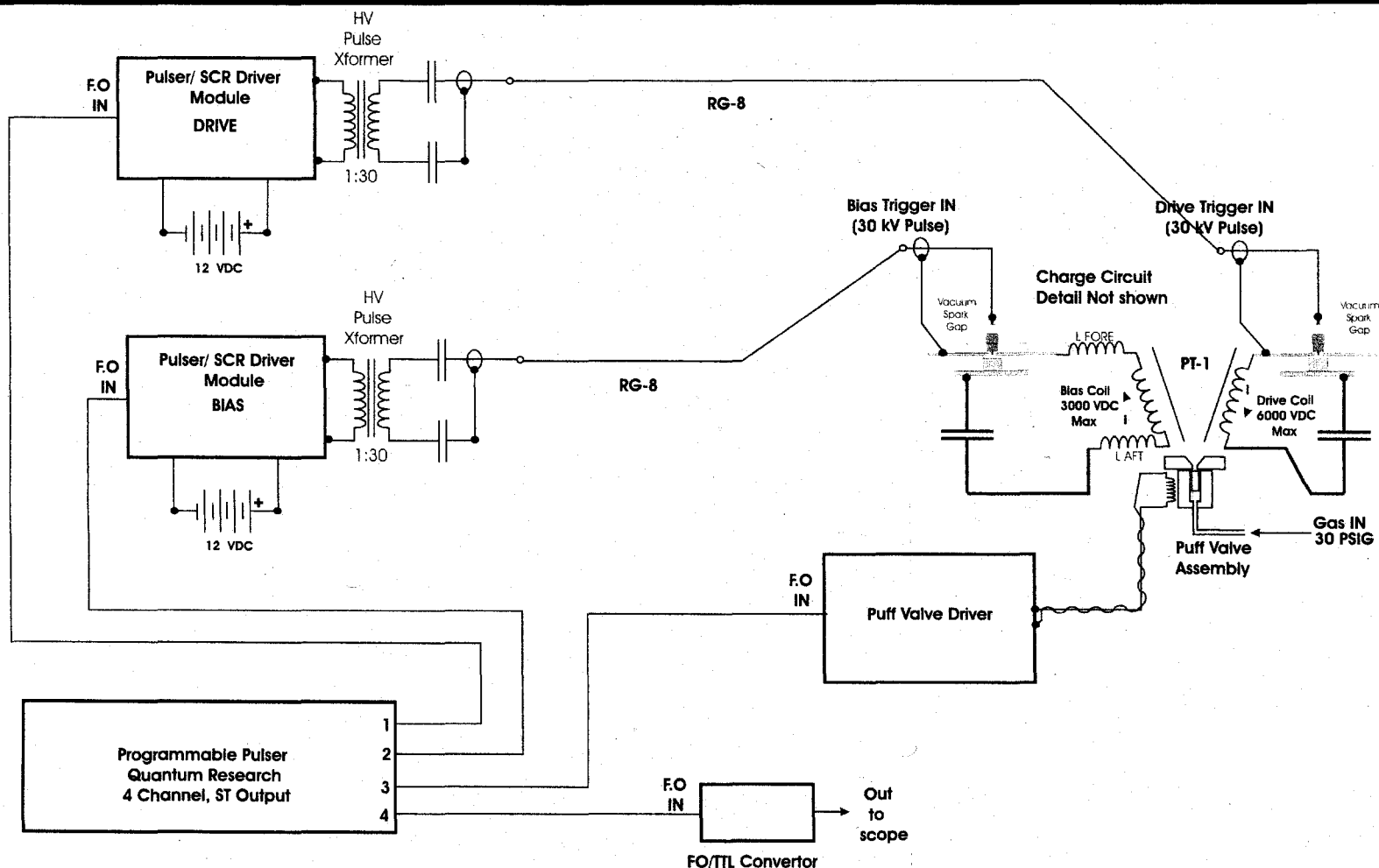
Reference: Martin, A.K. and Eskridge, R. H., "Electrical Coupling Efficiency of Inductive Plasma Accelerators", IOP J. Applied Phys. D.,



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Electrical Detail of the PT-1 . The puff valve is operated, then two capacitor banks are discharged via “vacuum spark gap” switches through the “Drive” and “Bias” coils with precise timing to form and eject a “plasmoid”

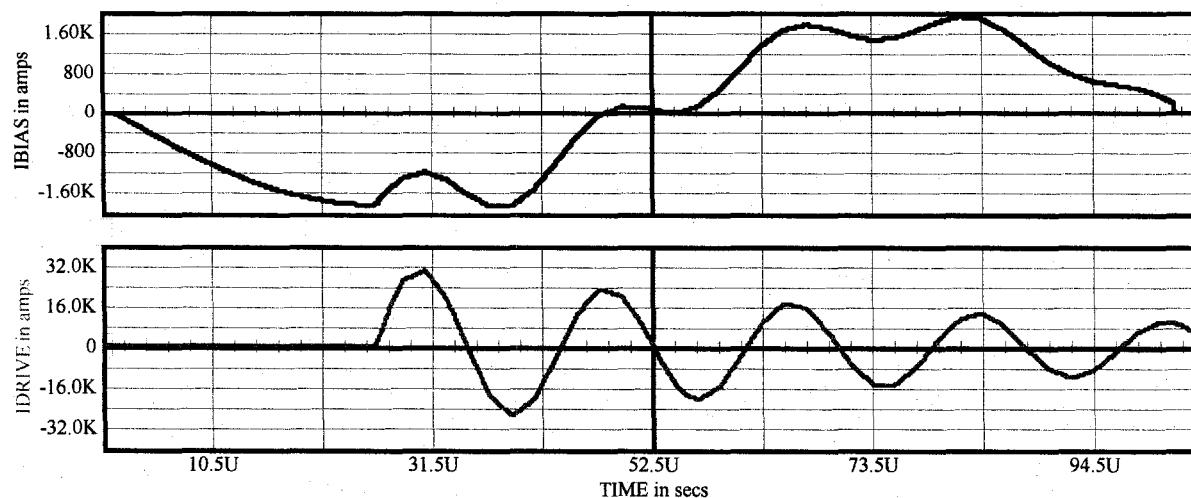


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PSPICE Model of PT-1 Thruster



Discharge current through "BIAS" and "DRIVE" coils. Extra inductance is added to the "BIAS" coil to slow it down relative to the "DRIVE" discharge. This circuit is without inductive recovery element

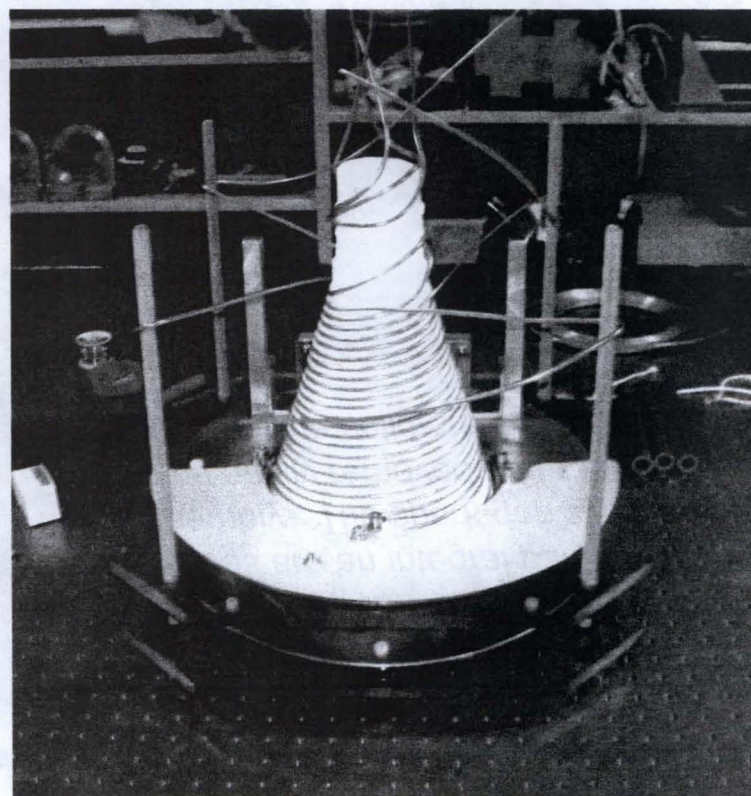
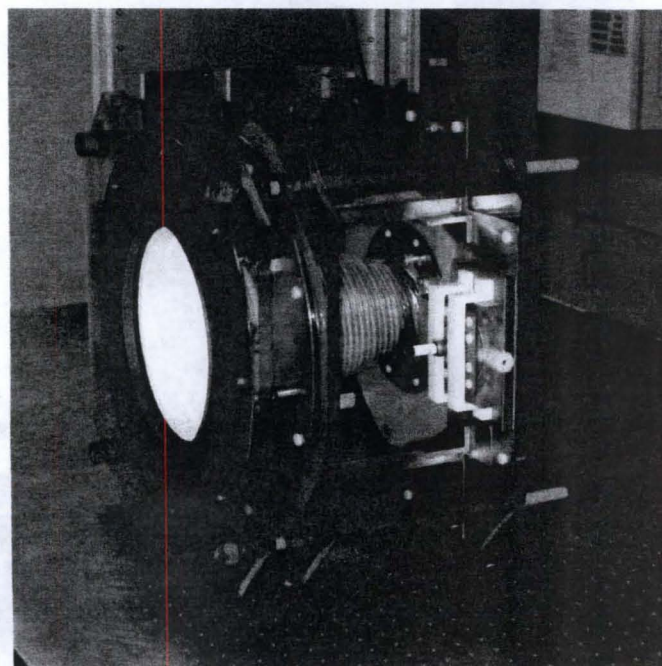
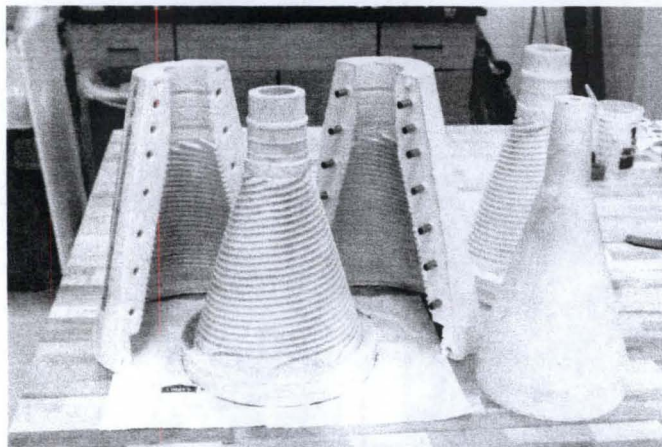


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LEFT: Ceramic coil form with Latex mold



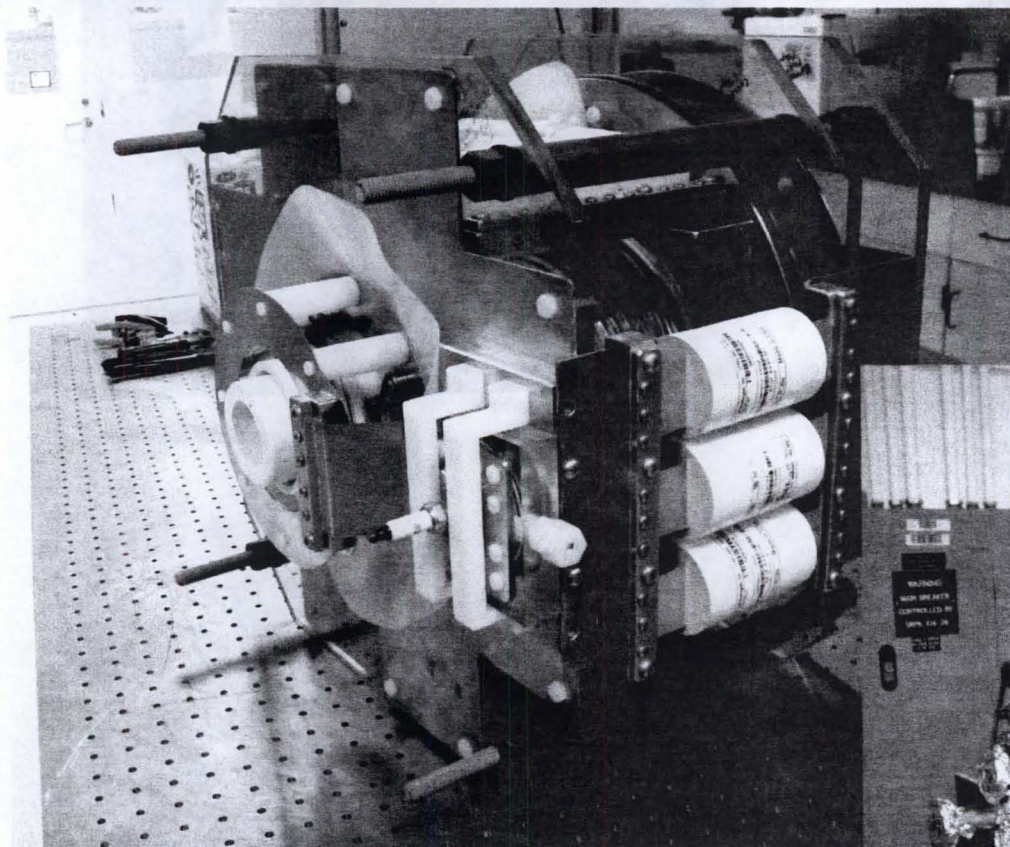
Above: Winding the coil
Left: PT1 Assembly (without capacitors installed)



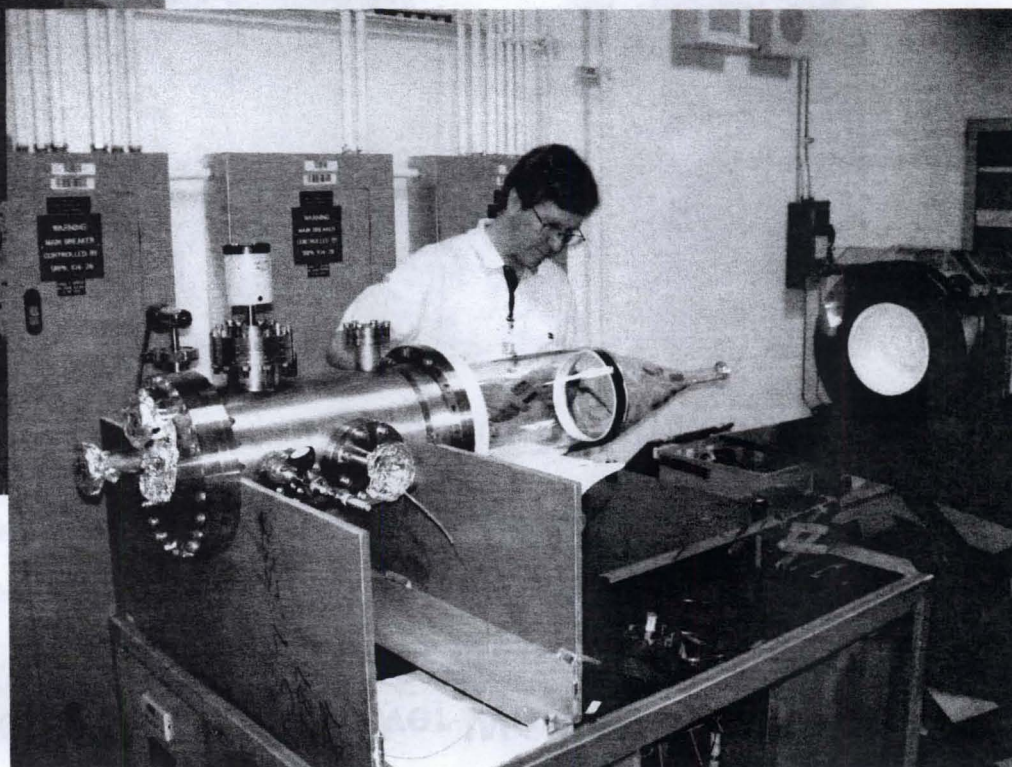
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Left: The completed PT-1 thruster. The capacitor banks and vacuum spark gap switches are an integral part of the thruster assembly. The spark gap switches are designed To be easily removed and replaced for evaluation of alternative solid-state switching technologies.

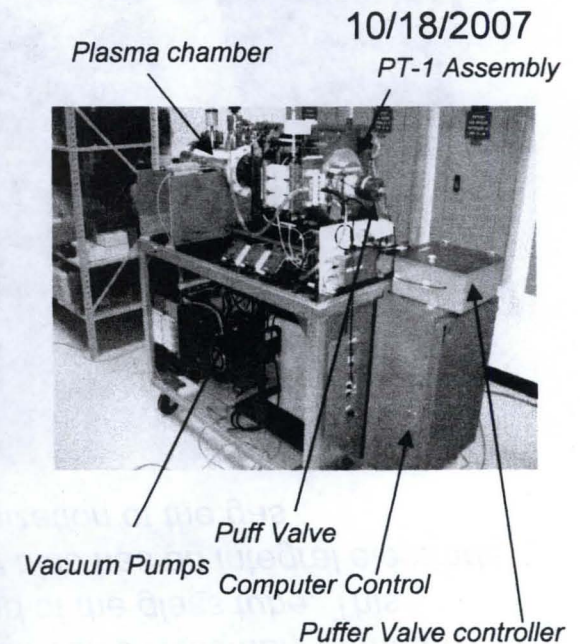
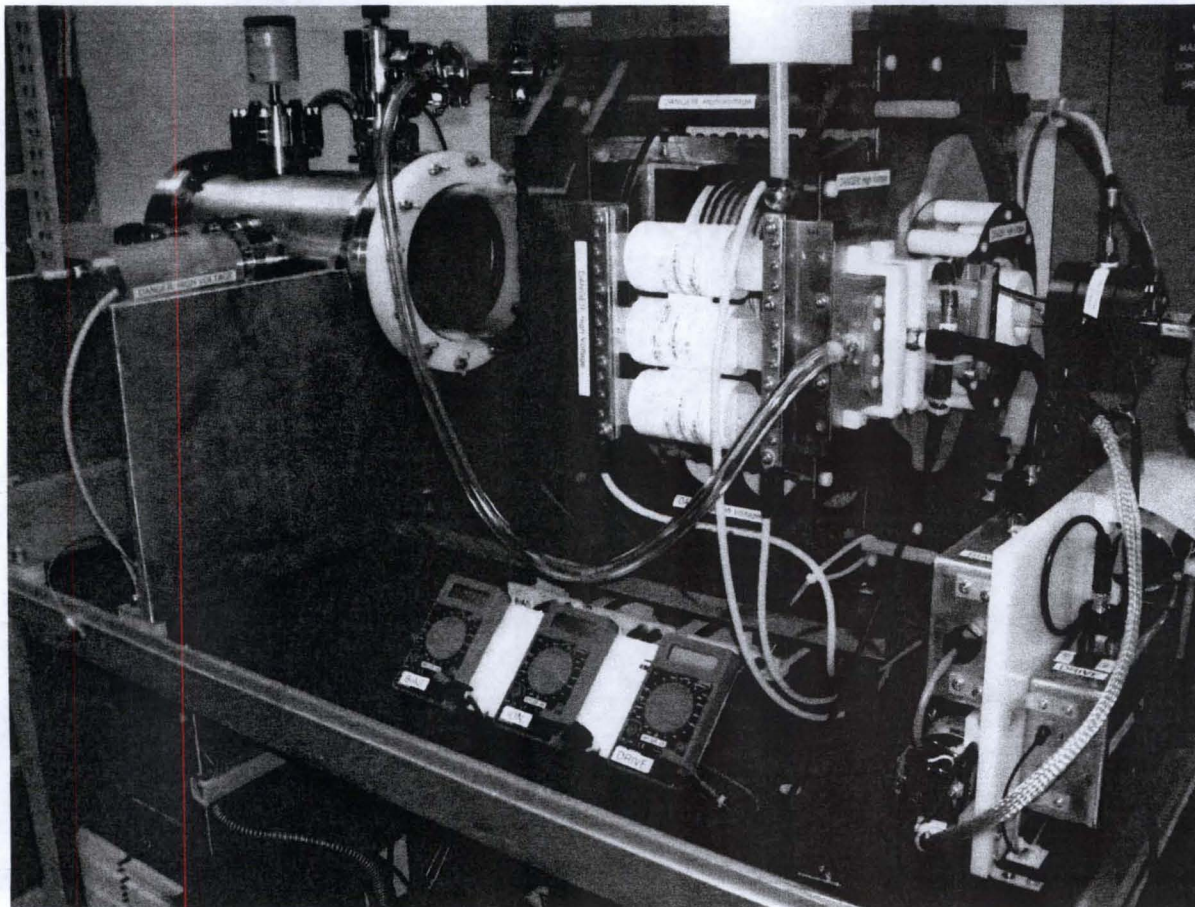


Right: The PT-1 thruster assembly is Mounted on a glass vacuum chamber for test and demonstration purposes. This setup is easily transportable for evaluation By NASA's partners

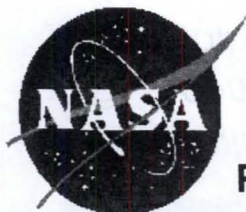


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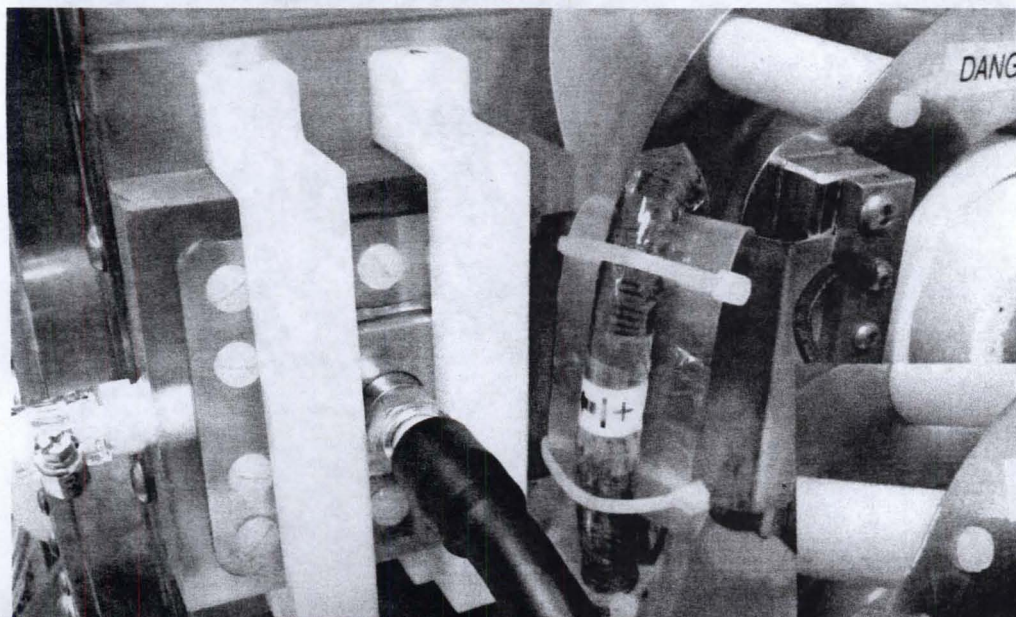
Fully-Integrated Plasmoid Thruster and vacuum plasma tube assembly. The complete system including control and power supplies are mounted on a cart for easy transport



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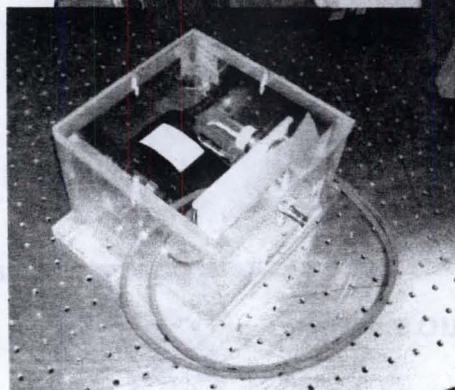
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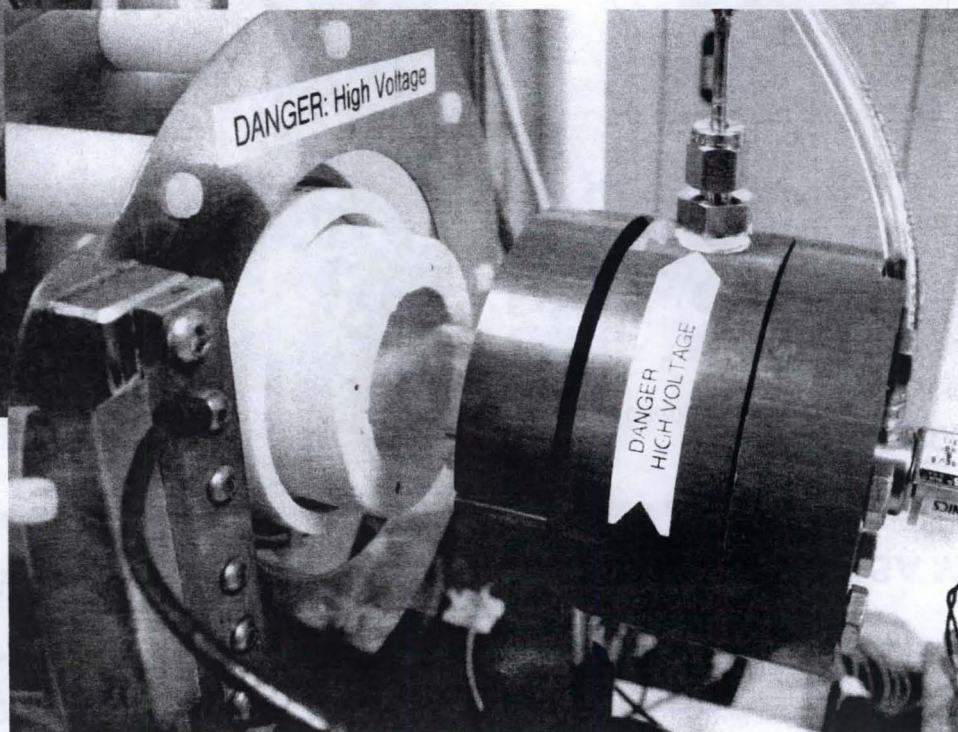


*Left: Vacuum Spark Gap
Switch with Rogowski Coil*

*Below: Puff valve Assembly mounted
on the end of the glass tube. This
assembly also has an integral electrode
for preionization of the gas*



*Inset Left: 30 KV trigger
transformer with SCR
switch assembly*

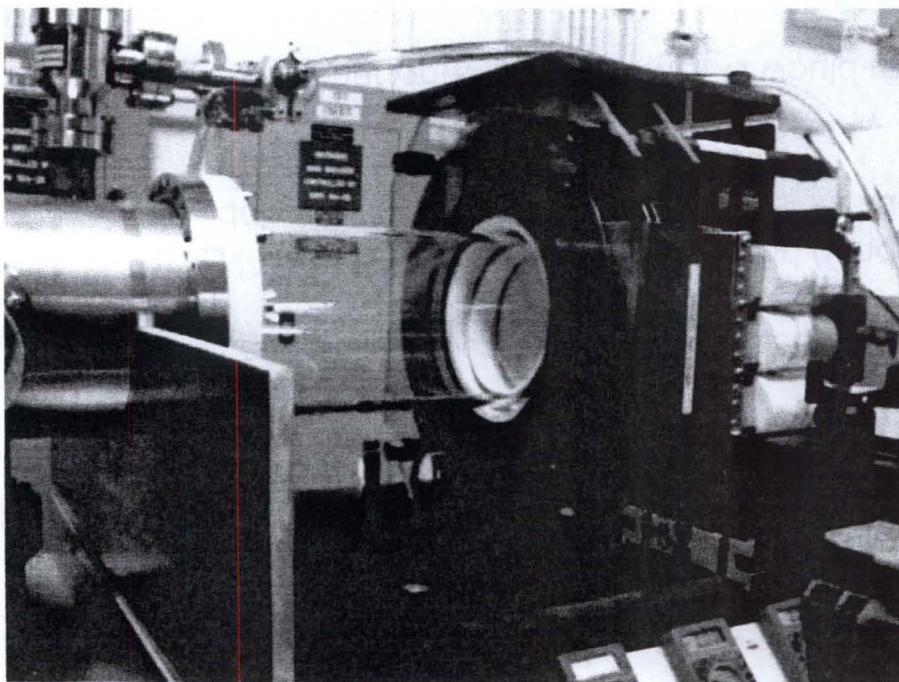




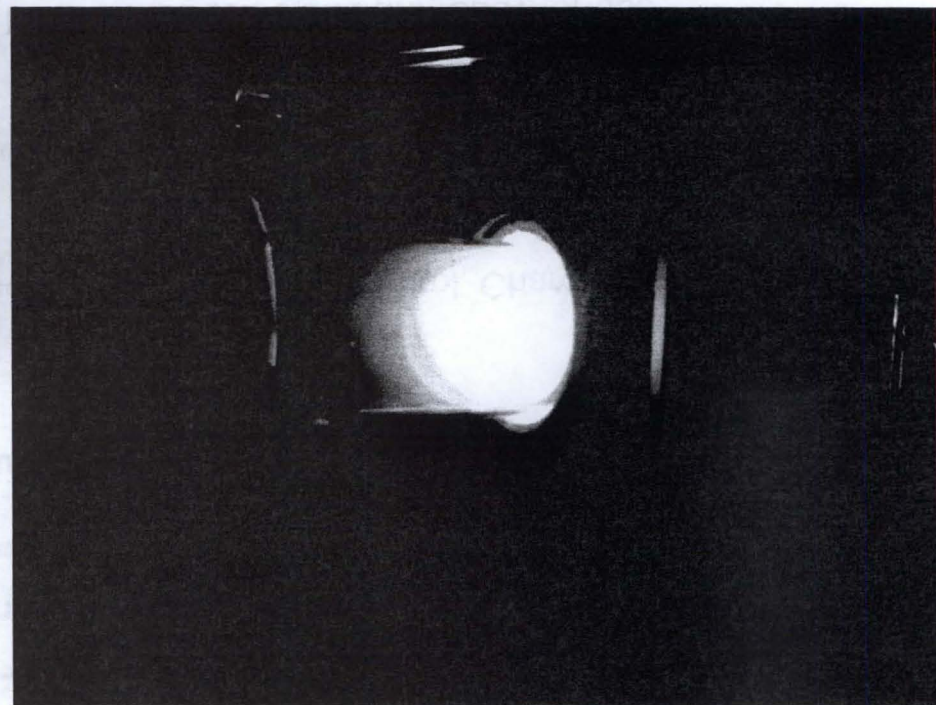
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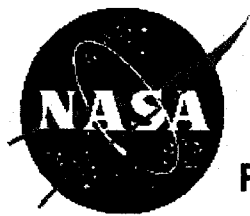
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Left: PT-1 ready for test firing.



Right: PT-1 operating with Argon test gas



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Status of PT-1

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All subsystems are completed and operational (Coil structure, Control, Charging, Triggers, Gas Puff, Vacuum etc....)

Preliminary testing has begun. Successful test firing with "Drive" and "Bias" has been made for Argon test gas.

Langmuir probes and B-Dot probes have been constructed and are ready for use

NASA MSFC participation is at end (funding depleted)- system is now ready for delivery to Radiance Technologies/ Auburn Space Power Institute and the University of South Alabama (Mobile , AL)

Additional work by NASA MSFC would require a partner and funding.